



Interpreting mm-wave sounder observations over deep convection

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High-frequency sounders **can resolve convection,**
so can we retrieve **convection intensity**
instead of surface rain?

What are the biggest difficulties for the forward modeling? (hydrometeors)

What are the biggest difficulties for assimilation? (" , biases, H₂O vapor)

Measurements don't amount to many independent pieces of info

Applications in addition to forecasting
(diagnostics)

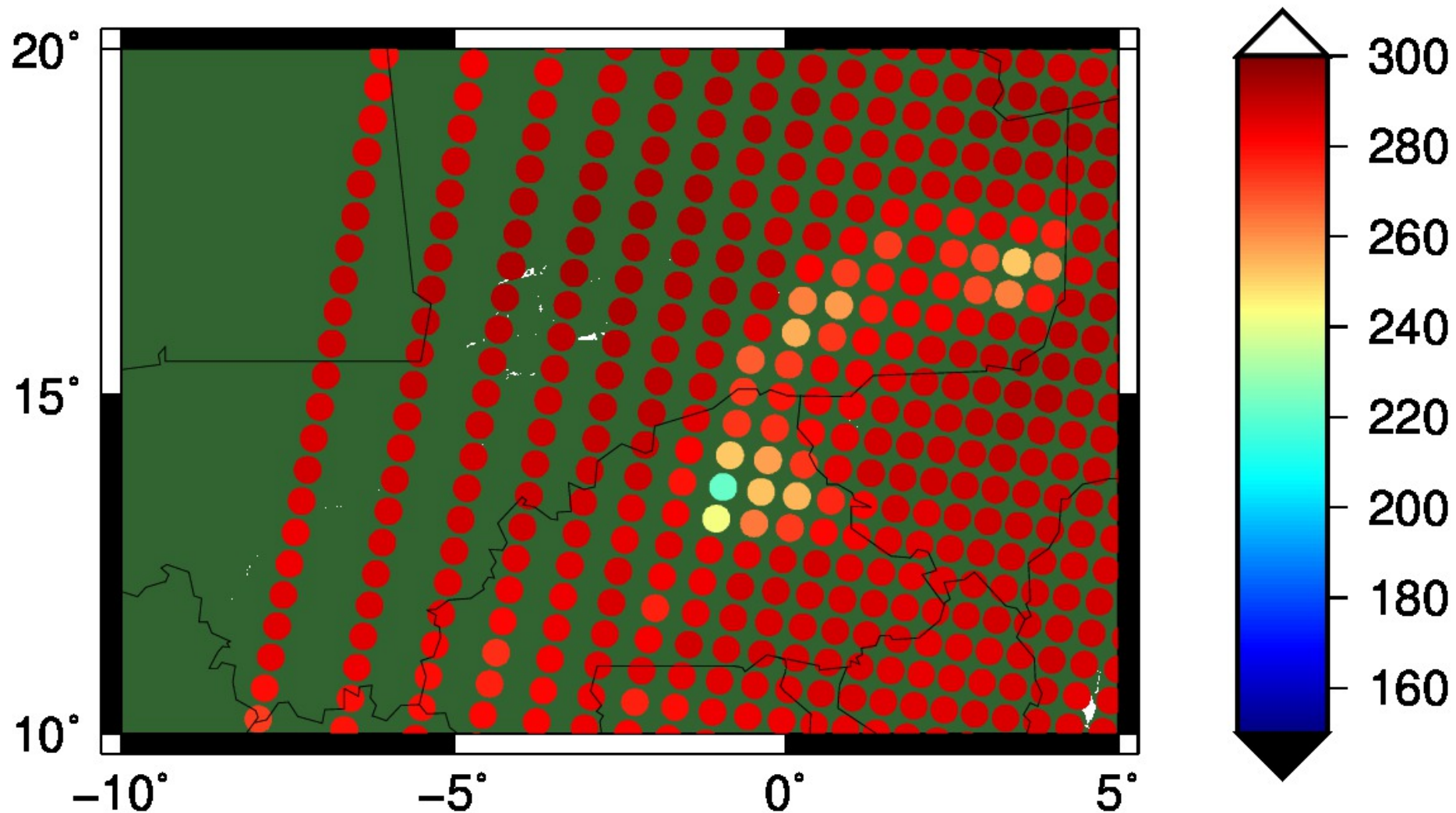


(resolution $\sim 40\text{km}$ at nadir)

Date: 07/24/2014

Time: 01:50:01

AMSU-A 89 GHz



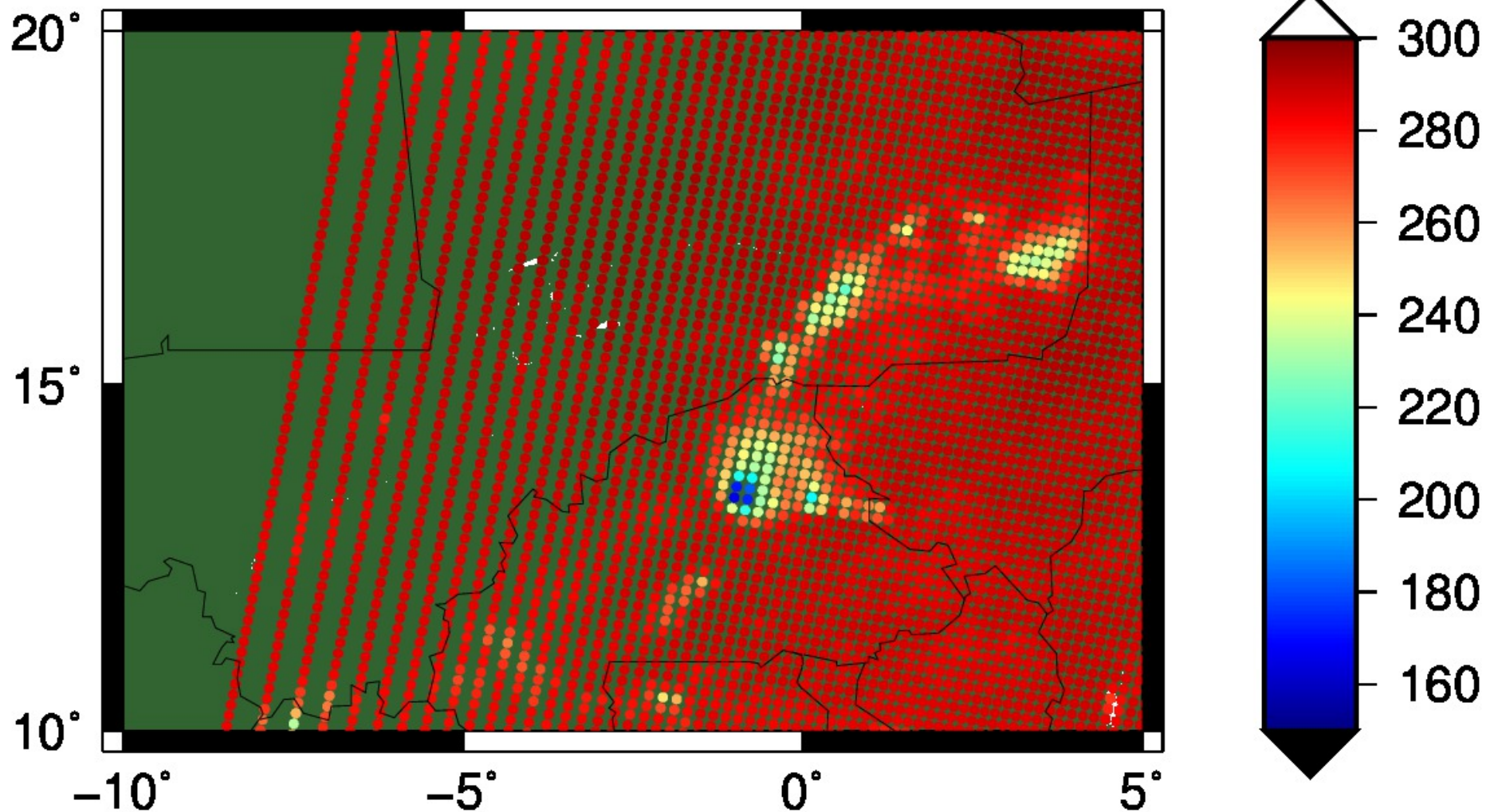


(resolution $\sim 15\text{km}$ at nadir)

Date: 07/24/2014

Time: 01:50:01

MHS 89 GHz



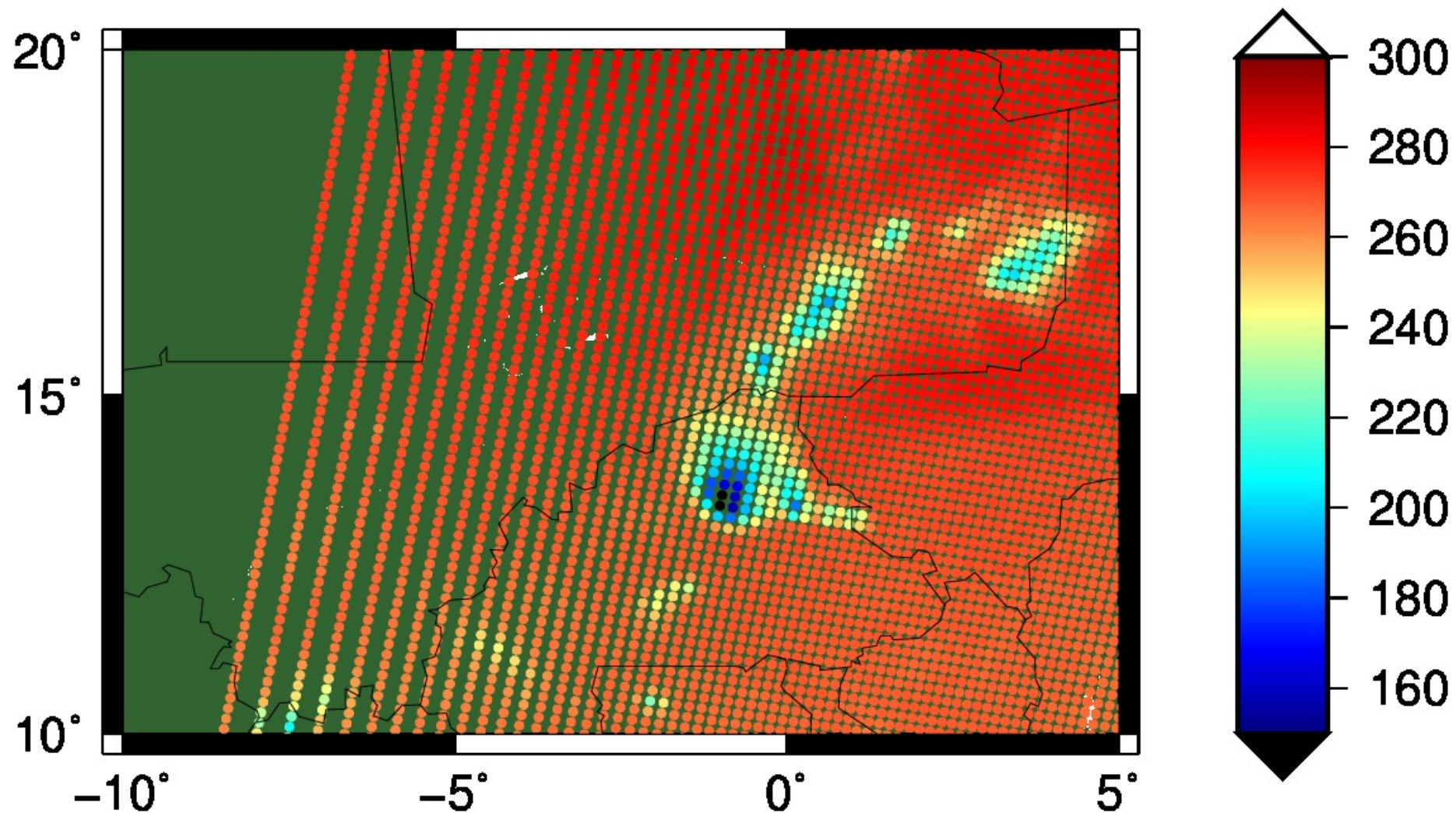


(resolution $\sim 15\text{km}$ at nadir)

Date: 07/24/2014

Time: 01:50:01

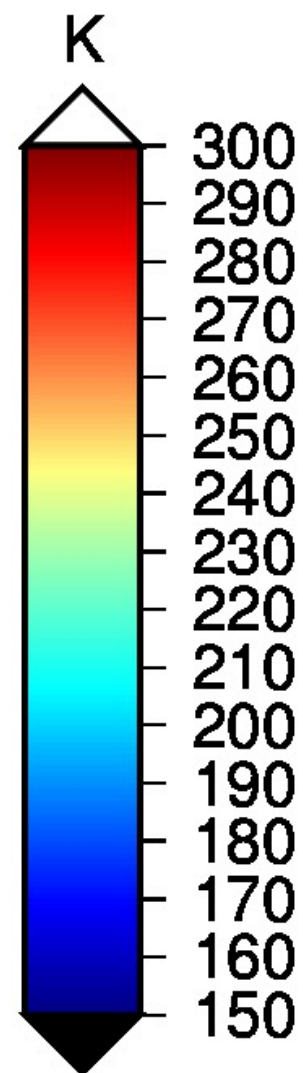
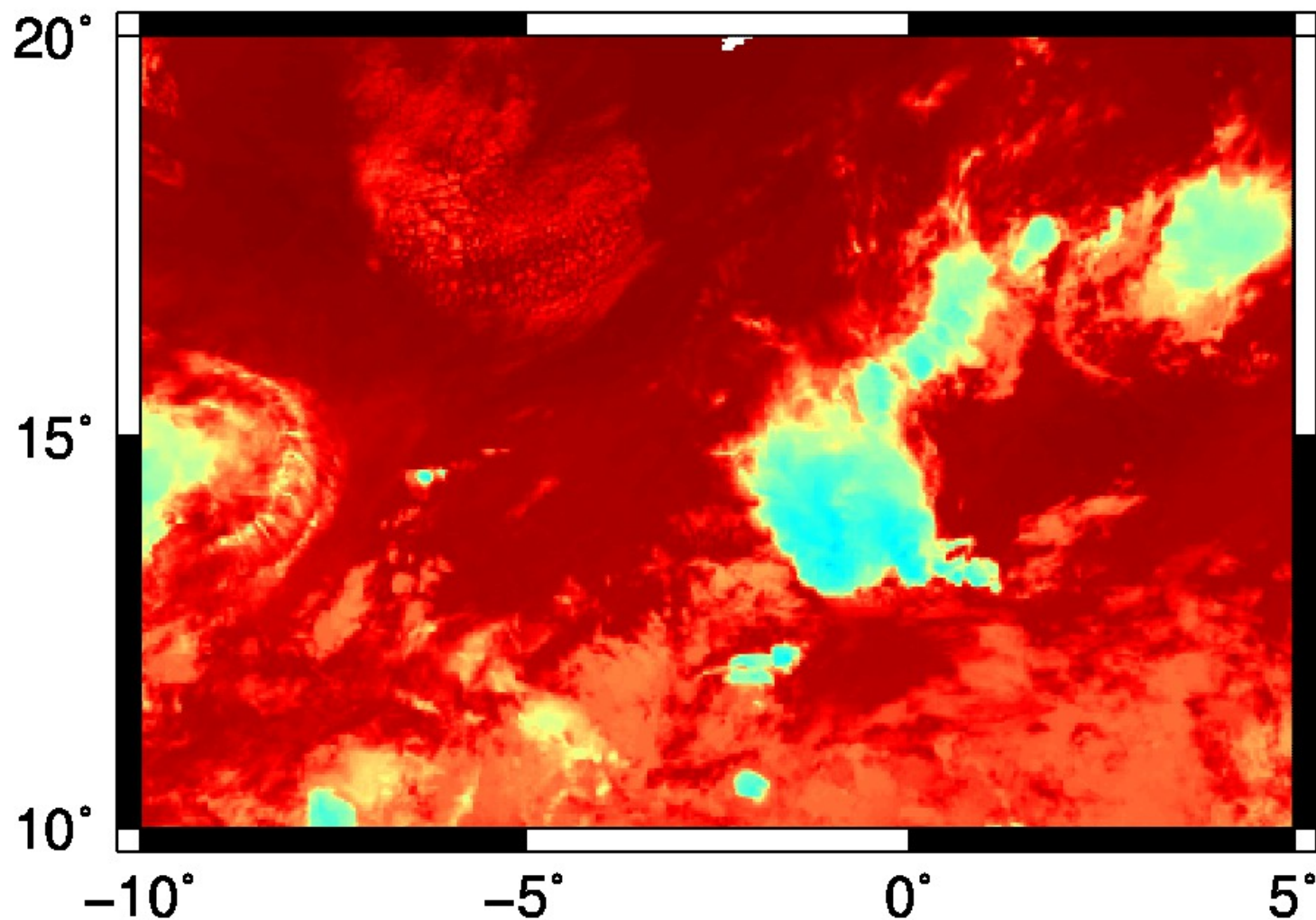
MHS 190.3 GHz





Geostationary 12 μm

02:00





⇒ with radiometer (MHS):

1. Use a database of nearly-simultaneous TRMM radar + MHS obs
2. Trust the radar as the truth relative to Condensed Water
3. Use sample conditional mean to **estimate vertical PC of CW from T_b** ,
and to **estimate mean T_b associated to CW**
4. Use CRM simulations to fit (T_b – conditional mean) to the (model) water vapor

0th step: detection

linear discriminant biased locally

⇒ add non-linear variables – for MHS, these are

$$T_6 = k_6 \frac{T_{186} - T_{184}}{T_{186} + T_{184}} \quad T_7 = k_7 \frac{T_{190} - T_{184}}{T_{190} + T_{184}} \quad T_8 = k_8 \frac{T_{190} - T_{186}}{T_{190} + T_{186}}$$

linear discriminant with non-linear variables works right out of the box



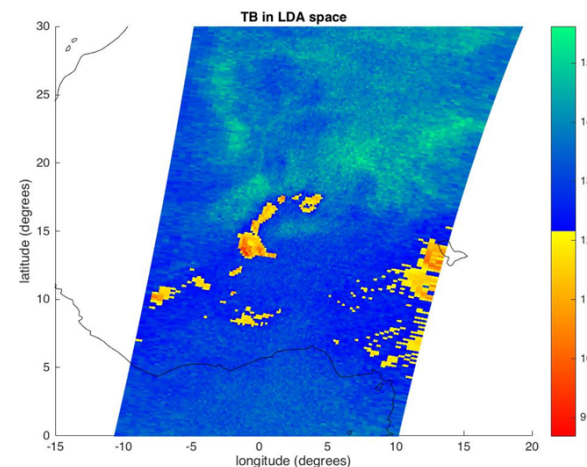
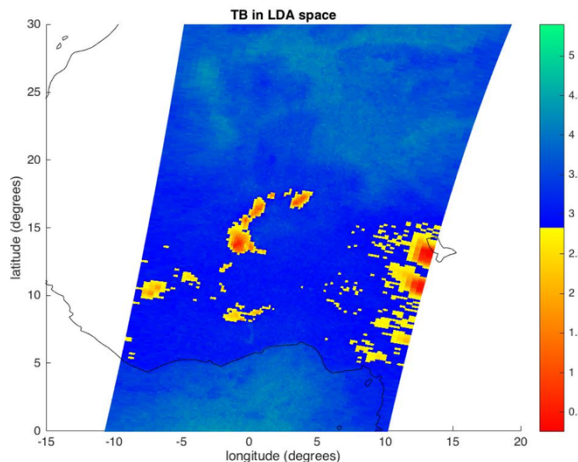
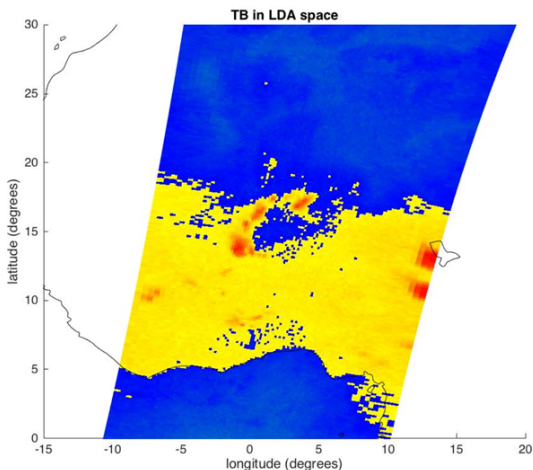
⇒ Semi-empirical approach with MHS:

0th step: detection (using database of coincident radar+radiom obs)
linear discriminant biased locally

⇒ add non-linear variables – for MHS, these are

$$T_6 = k_6 \frac{T_{186} - T_{184}}{T_{186} + T_{184}} \quad T_7 = k_7 \frac{T_{190} - T_{184}}{T_{190} + T_{184}} \quad T_8 = k_8 \frac{T_{190} - T_{186}}{T_{190} + T_{186}}$$

linear discriminant with non-linear variables works right out of the box





⇒ Semi-empirical approach with MHS:

1. Use a database of nearly-simultaneous radar + radiometer obs

0th step: detection using linear discriminant with non-linear variables

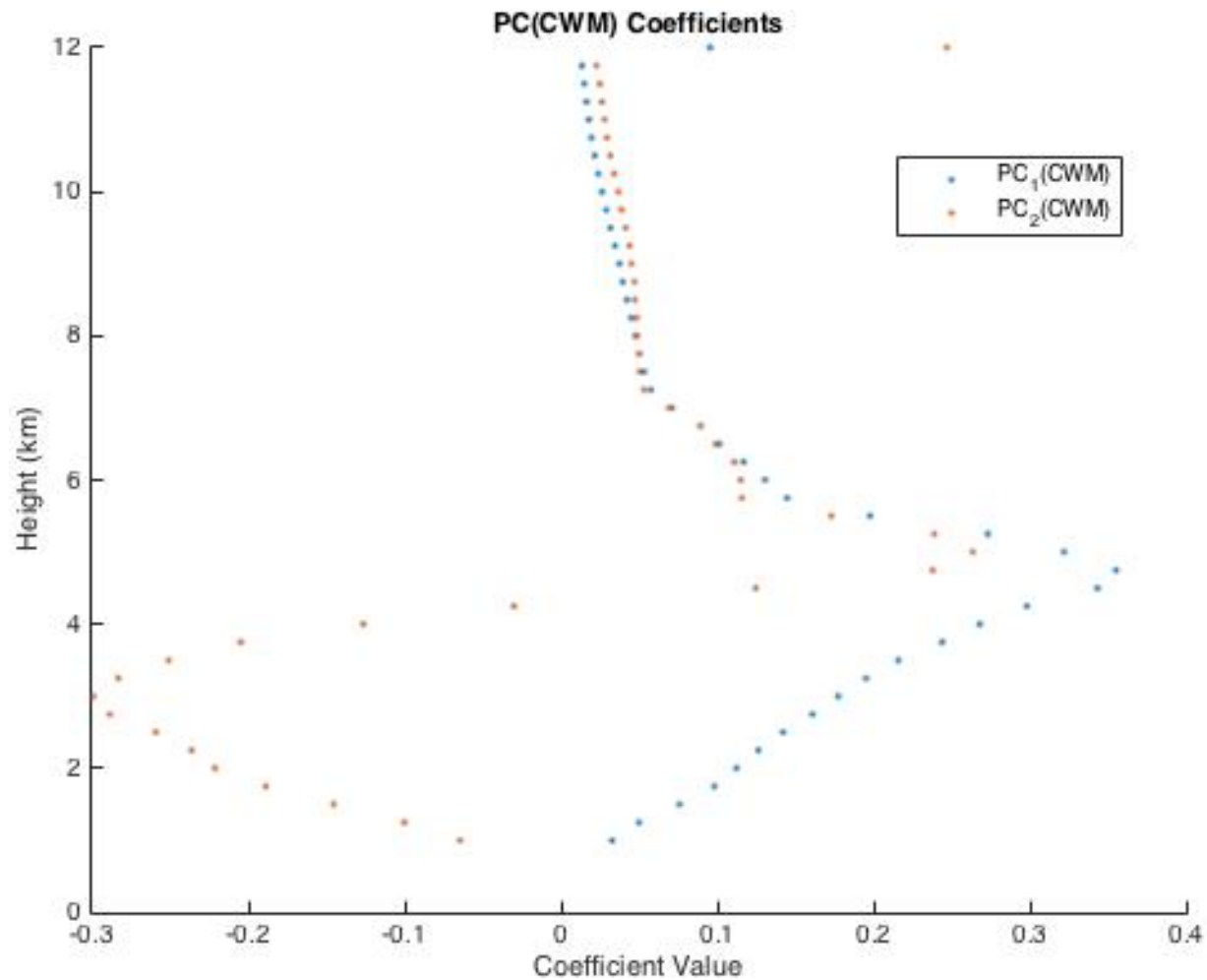
0'th step: In the rain, use clear-air cPC_2 , cPC_3 , cPC_4 , ...
instead of T_b themselves

Then use in-rain $rPC_1(cPC_2, cPC_3, cPC_4, \dots)$ & $rPC_2(cPC_2, cPC_3, cPC_4, \dots)$
instead of T_b themselves

(and similarly use $vPC1(CW)$ and $vPC2(CW)$ instead of vertical profile of CW)



⇒ Semi-empirical approach:

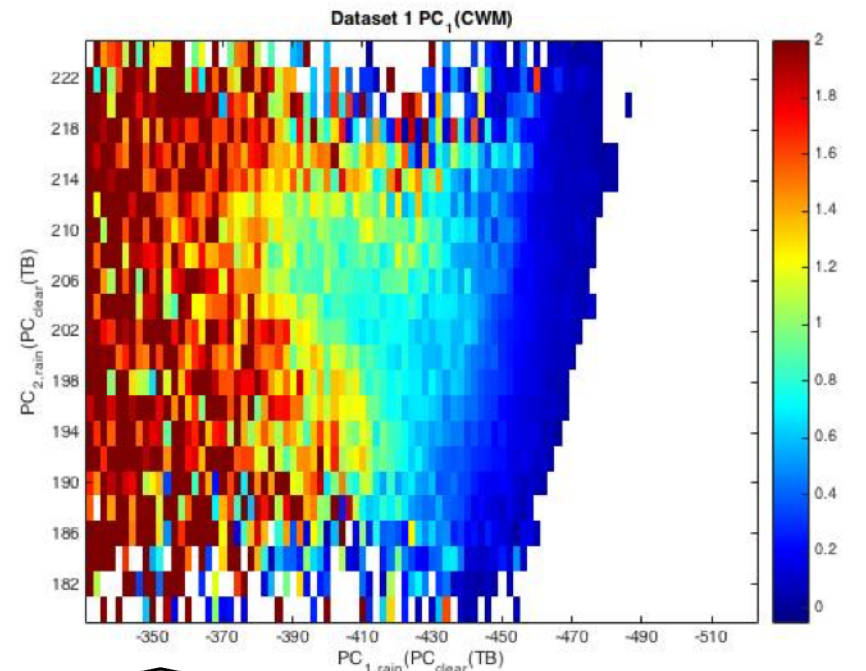
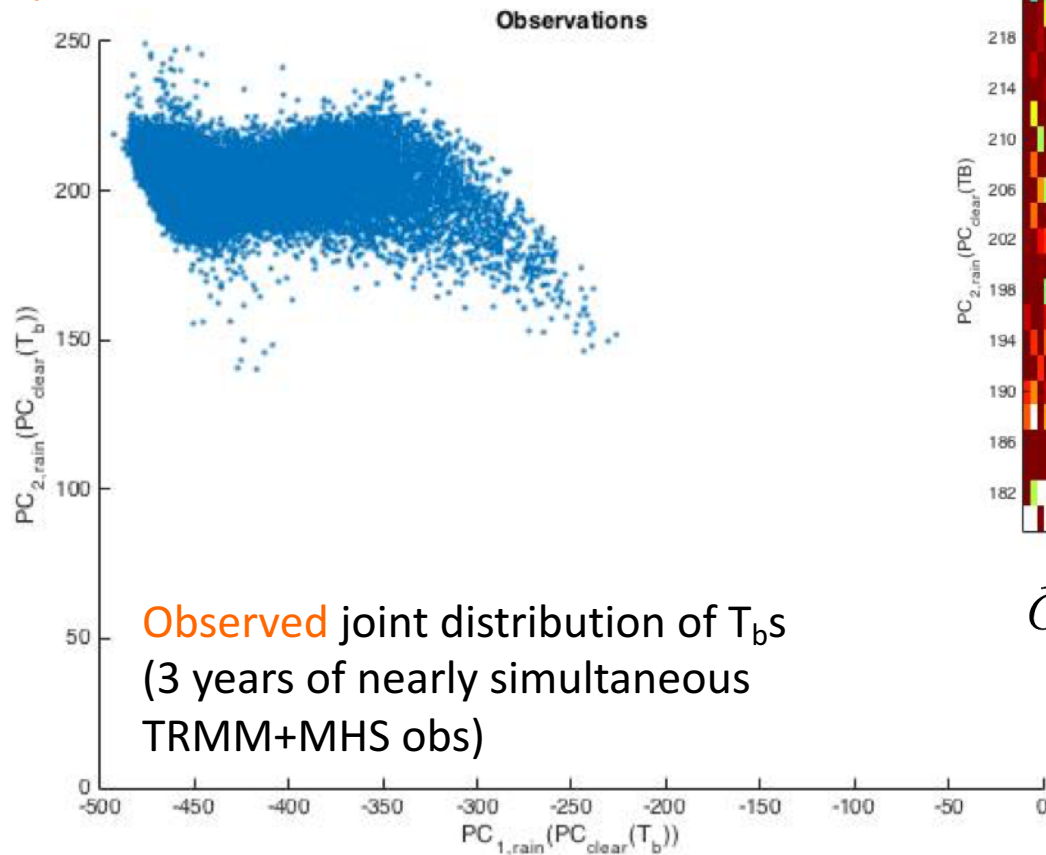


$vPC1(CW)$ and $vPC2(CW)$



⇒ Semi-empirical approach:

Step 1 – mean relations

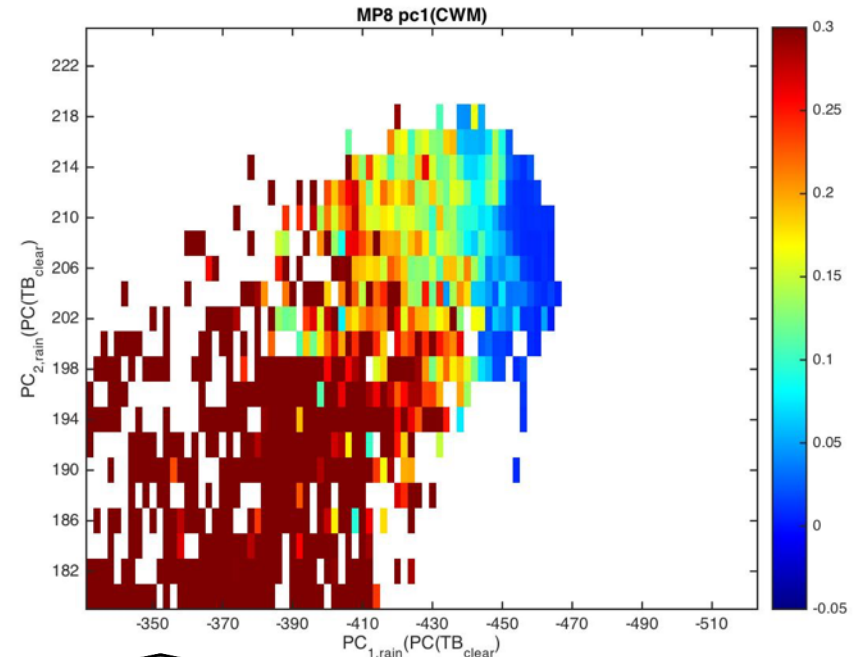
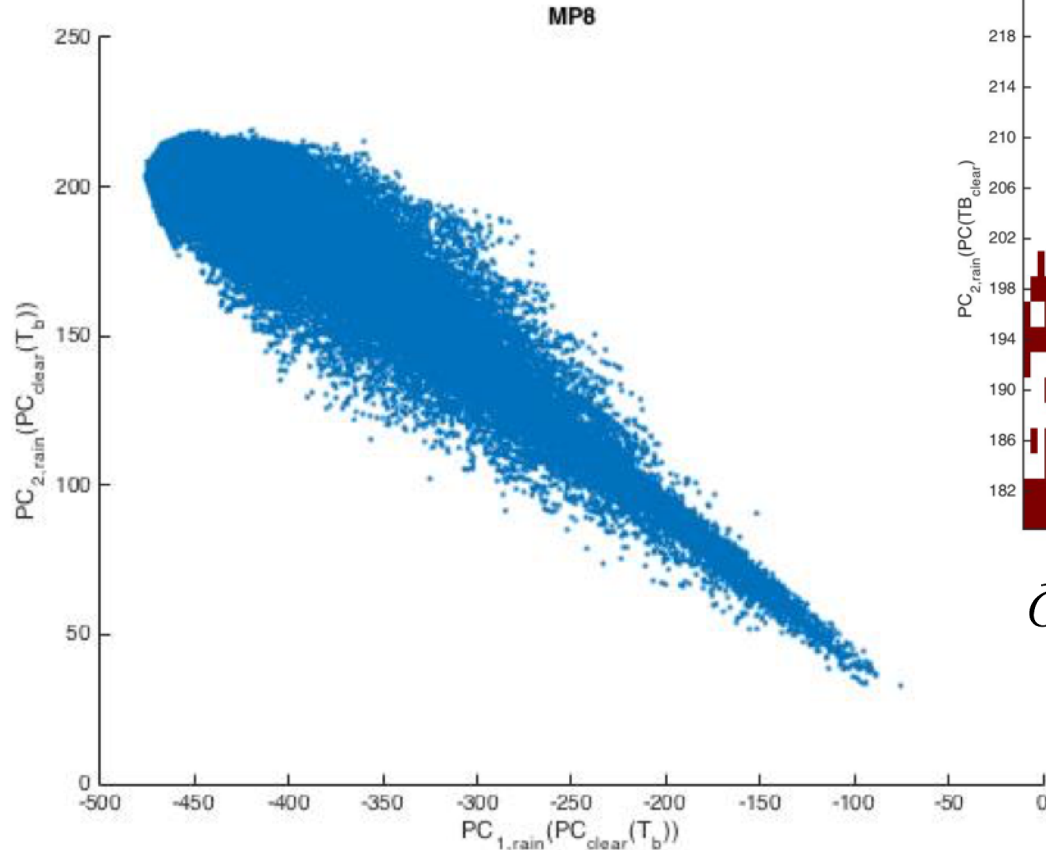


$$\widehat{CWM}_1 = E\{PC_1(CWM) | T_1'', T_2''\}$$



⇒ Semi-empirical approach:

Step 1 – mean relations



$$\widehat{CWM}_1 = E\{PC_1(CWM) | T_1'', T_2''\}$$

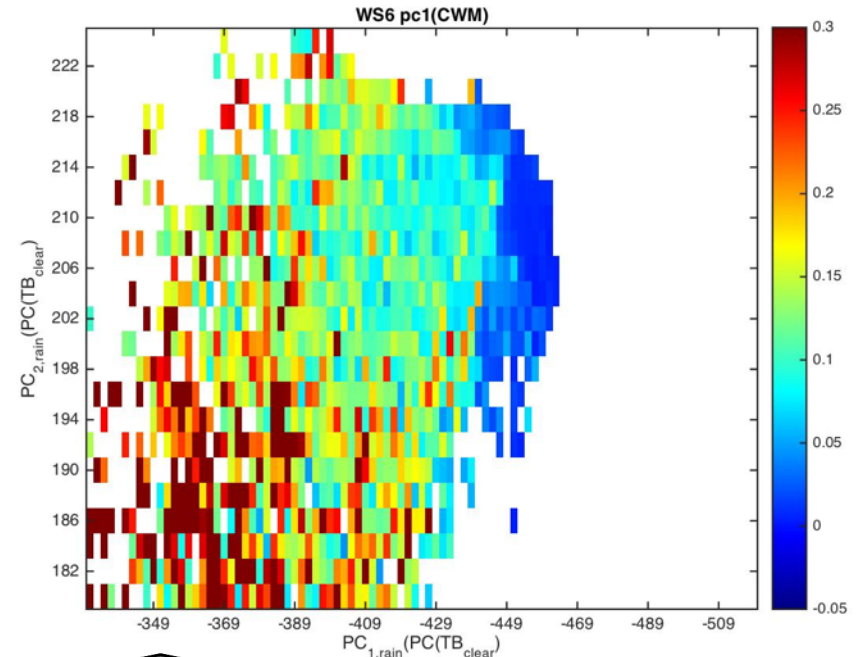
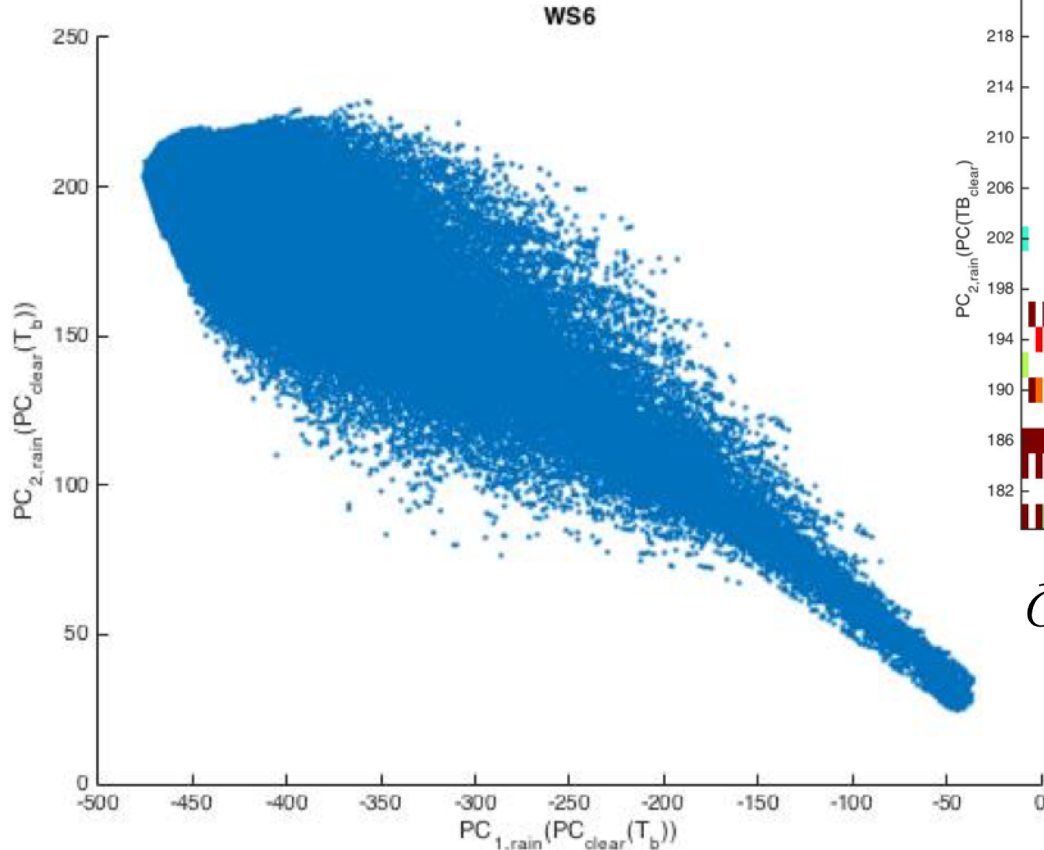
Modeled joint distribution of T_b s
10 consecutive instants (10mins apart) of Isabel

MP8 microphysics



⇒ Semi-empirical approach:

Step 1 – mean relations



$$\widehat{CWM}_1 = E\{PC_1(CWM) | T_1'', T_2''\}$$

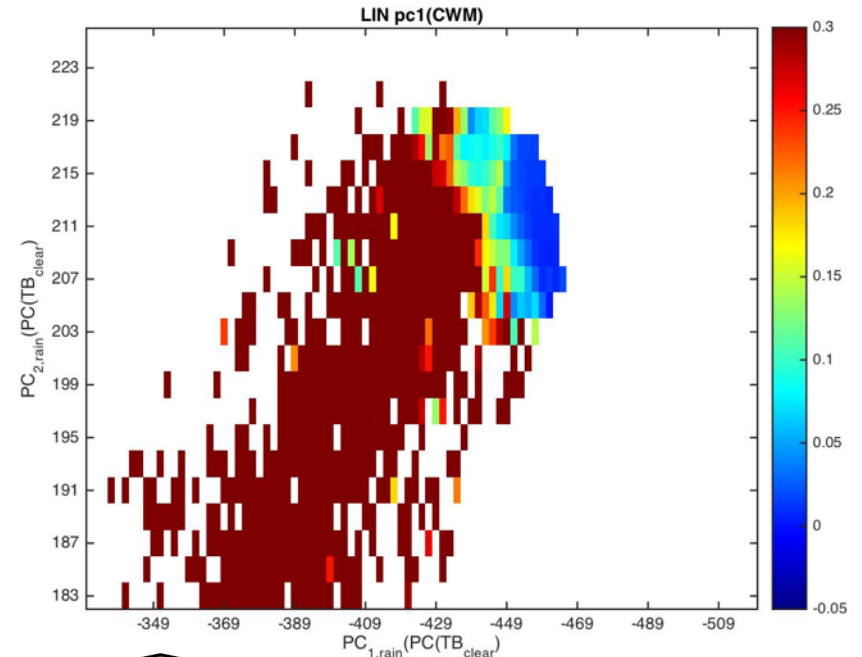
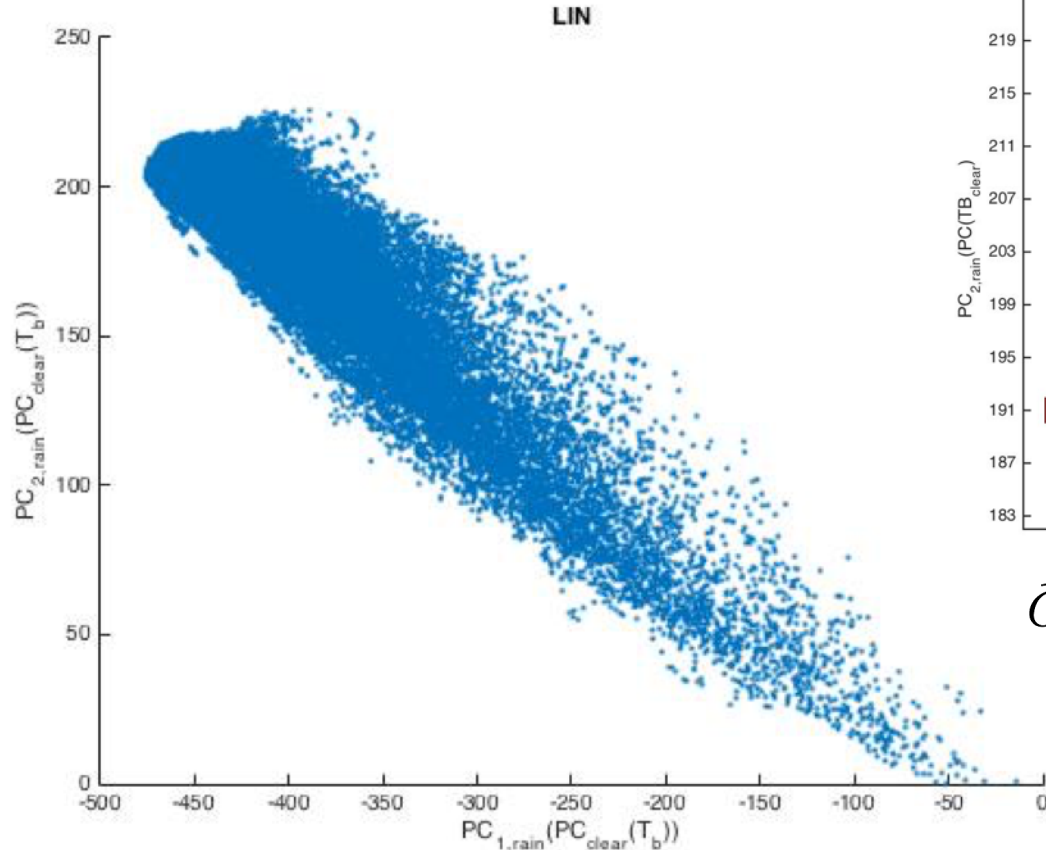
Modeled joint distribution of T_b s
10 consecutive instants (10mins apart) of Isabel

WSM6 microphysics



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Step 1 – mean relations



$$\widehat{CWM}_1 = E\{PC_1(CWM) | T_1'', T_2''\}$$

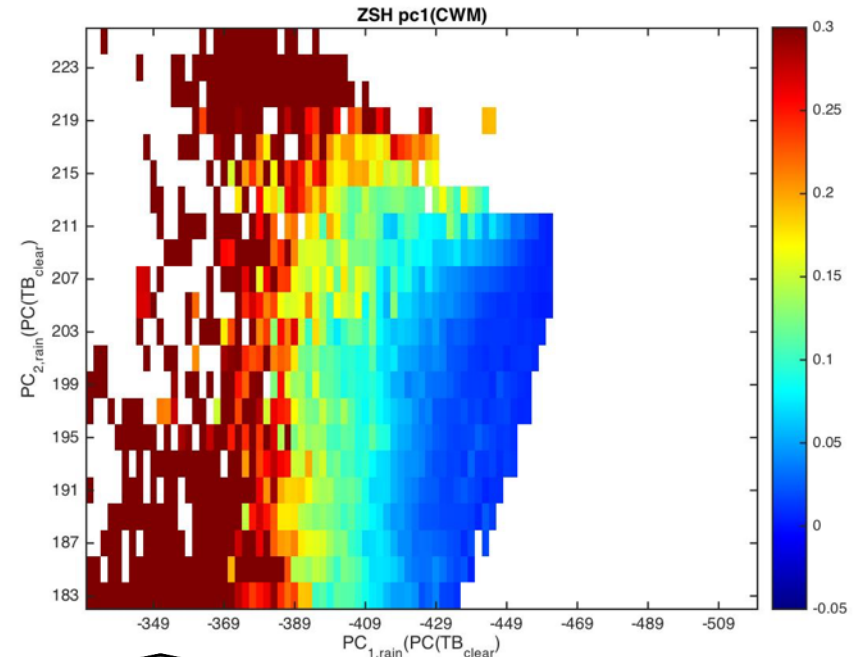
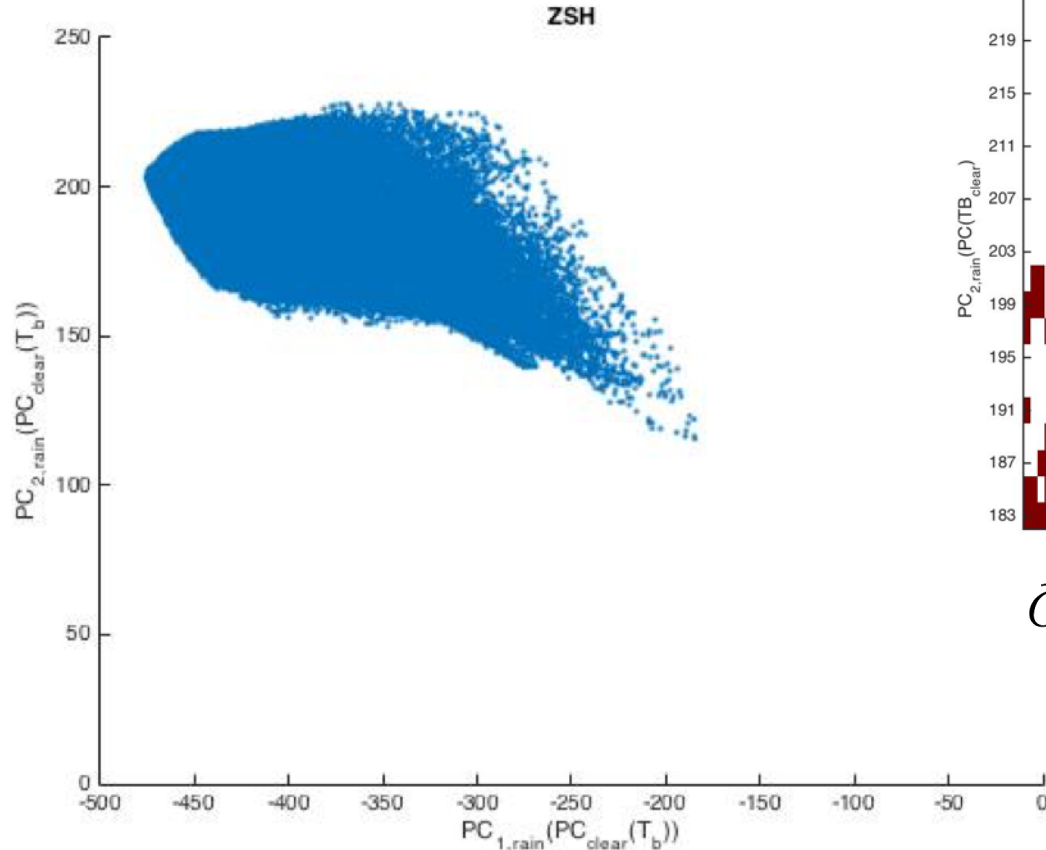
Modeled joint distribution of T_b s
10 consecutive instants (10mins apart) of Isabel

Lin microphysics



⇒ Semi-empirical approach:

Step 1 – mean relations



$$\widehat{CWM}_1 = E\{PC_1(CWM) | T_1'', T_2''\}$$

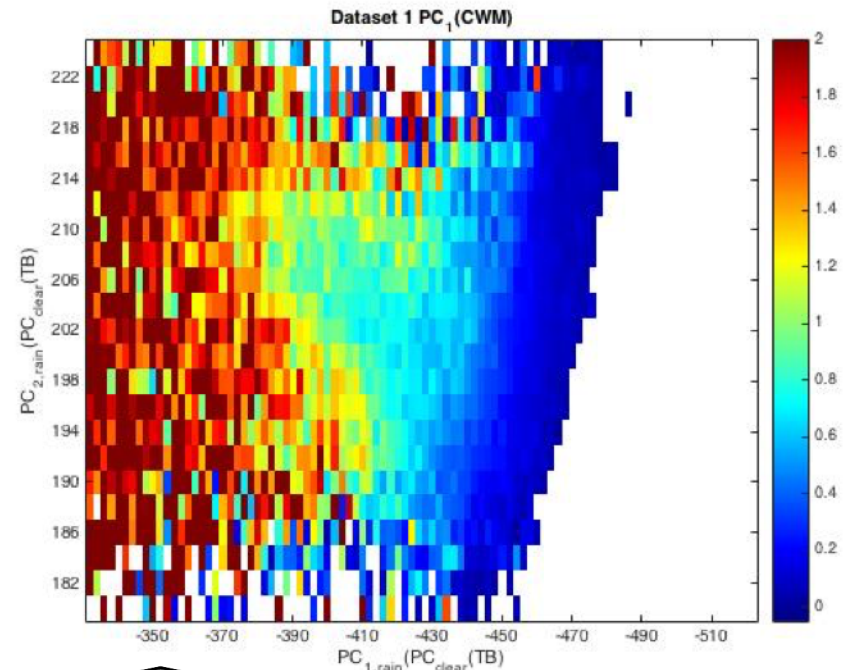
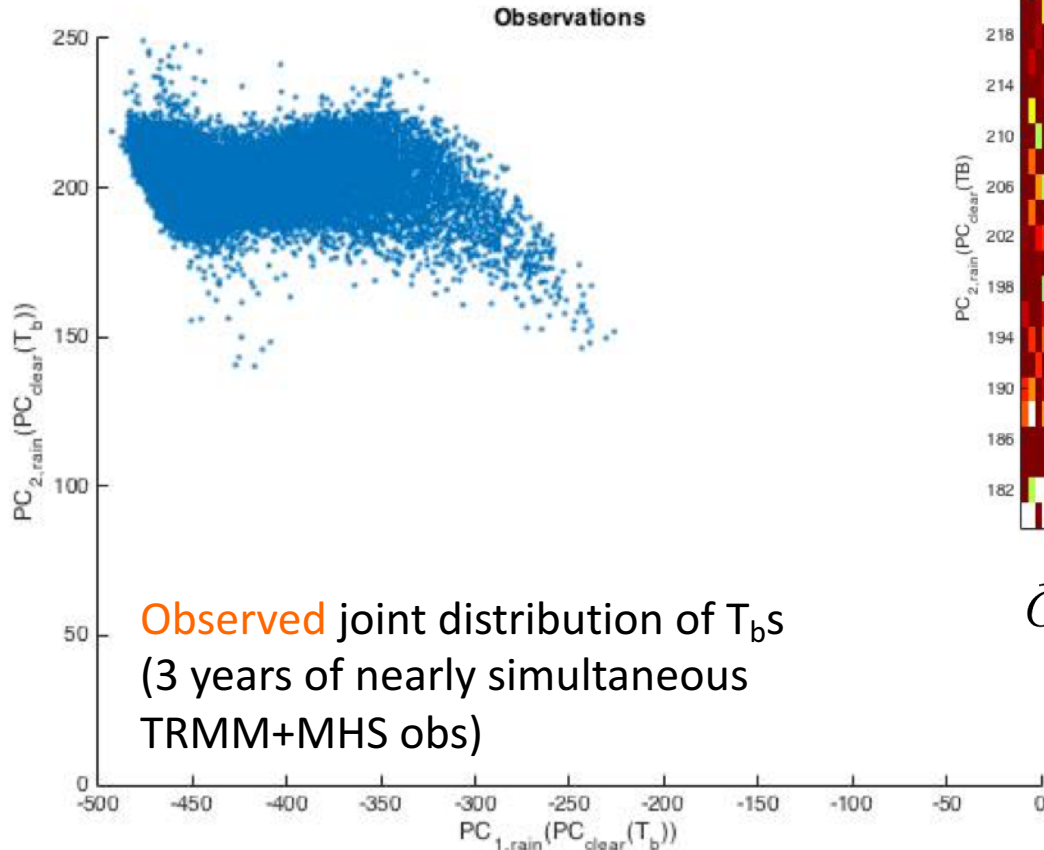
Modeled joint distribution of T_bs
10 consecutive instants (10mins apart) of Isabel

Oosy-zsh microphysics



⇒ Semi-empirical approach:

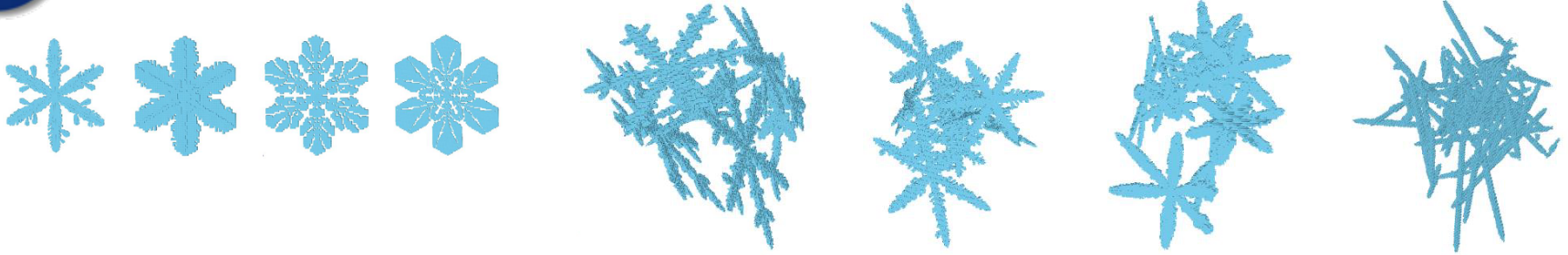
Step 1 – mean relations



$$\widehat{CWM}_1 = E\{PC_1(CWM) | T_1'', T_2''\}$$



What is “OOSy-zsh” Hydrometeor representation?



Schmitt & Heymsfield 2010: for individual hydrometeor,

$$\text{mass} = a D_{\max}^b$$

with $0.004 < a < 0.009$ and $1.8 < b < 2.4$

So: use 32 sample (a,b) and sort Kuo's synthetic hydrometeors into one of the 32 classes

Then sample (μ, Λ) , and for each sample value in each (a,b) class, calculate D_{MaWe} and σ_{MaWe}

Finally, keep only those for which

$$0.2 < D_{\text{MaWe}}/CW^{0.17} < 2 \quad \text{and} \quad 0.15 < \sigma_{\text{MaWe}}/D_{\text{MaWe}}^{1.3} < 0.6$$



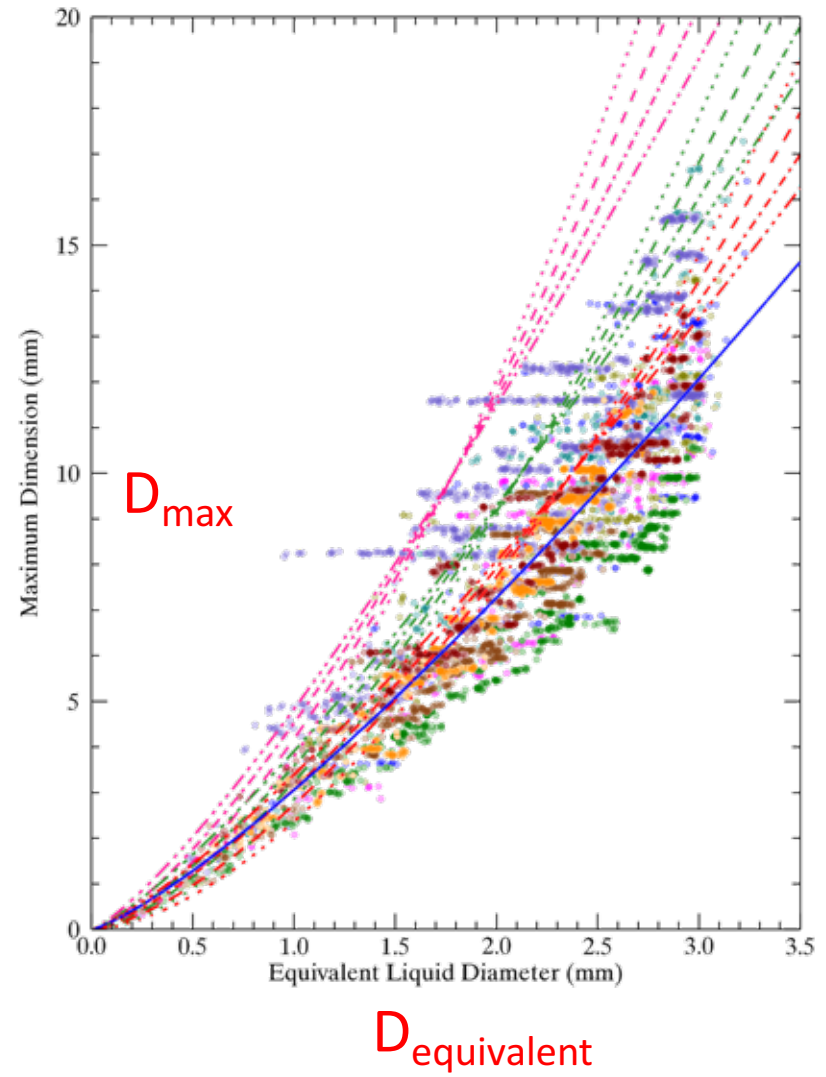
What is “OOSy-zsh” Hydrometeor representation?

Schmitt & Heymsfield 2010:

$$\text{mass} = a D_{\text{max}}^b$$

with $0.004 < a < 0.009$ and $1.8 < b < 2.4$

expect: $D_{\text{max}} = [\pi/(6a)]^{1/b} (\text{Dequiv})^{3/b}$





⇒ **non-empirical part of Semi-empirical approach:**

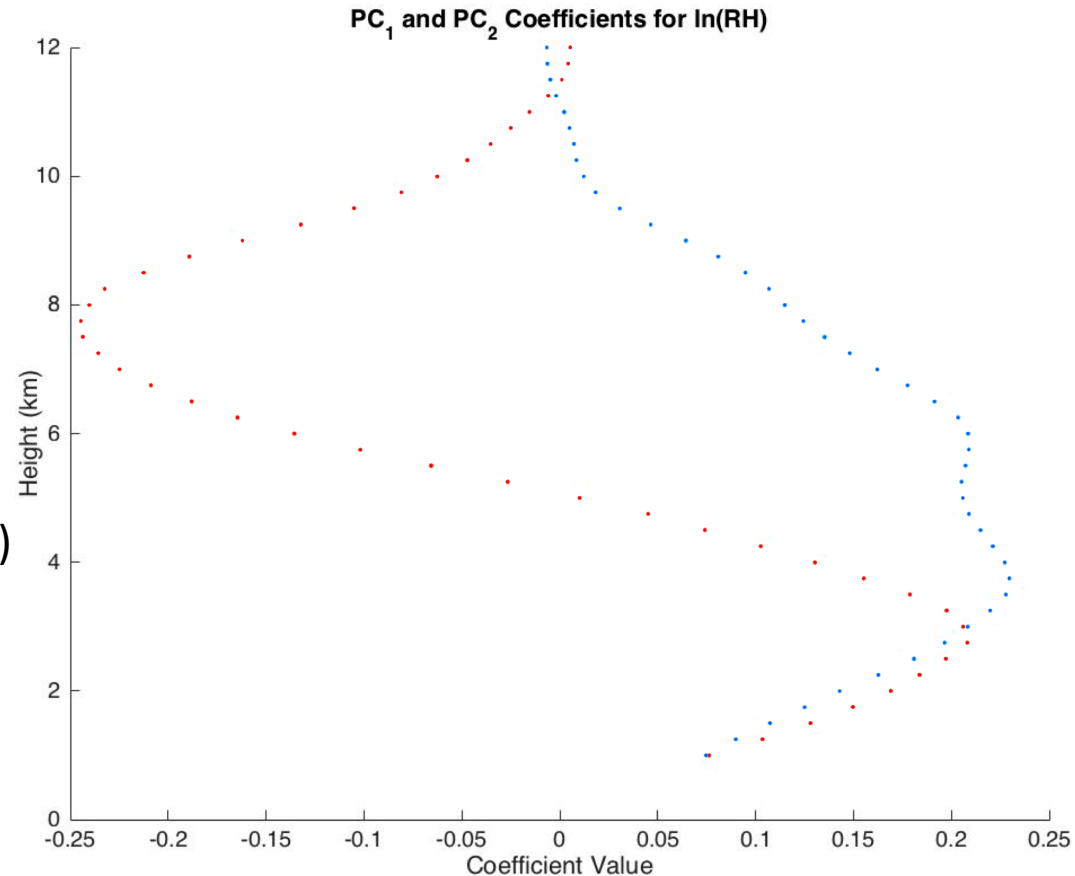
Step 2 – departure from mean

Accepting the empirical mean relation between T and CW ,

use model sims to express dependence of residual

$$\Delta T'' = (T'')_{\text{MHS}} - E(T'' | PC_1(CW), PC_2(CW))$$

on water vapor



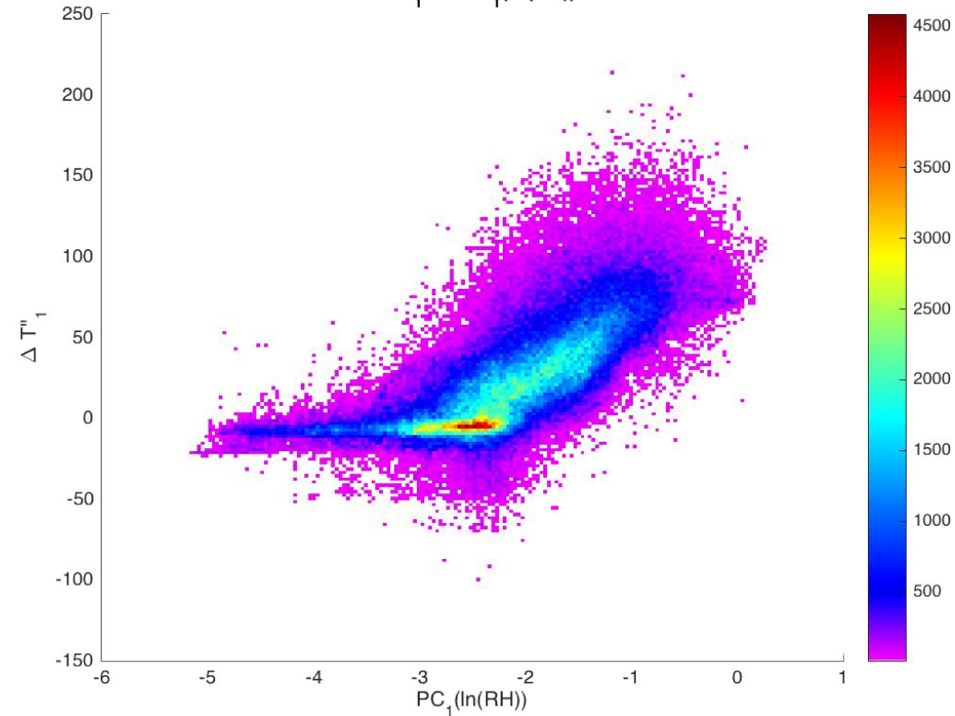
⇒ **look for correlation between ΔT and vPCs of RH ...**



⇒ look for correlation between ΔT and vPCs of RH:

Step 2 – departure from mean

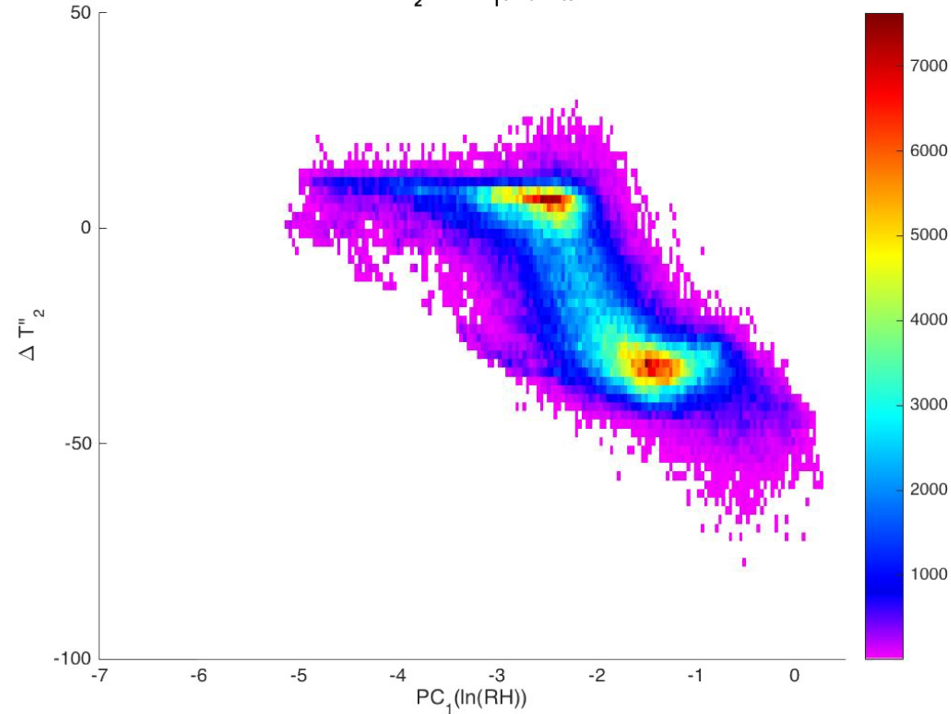
$\Delta T''_1$ vs. $PC_1(\ln(RH))$



$$\Delta T''_1 = (T''_1)_{\text{MHS}} - E(T''_1 | PC_1(CW), PC_2(CW))$$

$$\Delta T''_2 = (T''_2)_{\text{MHS}} - E(T''_2 | PC_1(CW), PC_2(CW))$$

$\Delta T''_2$ vs. $PC_1(\ln(RH))$

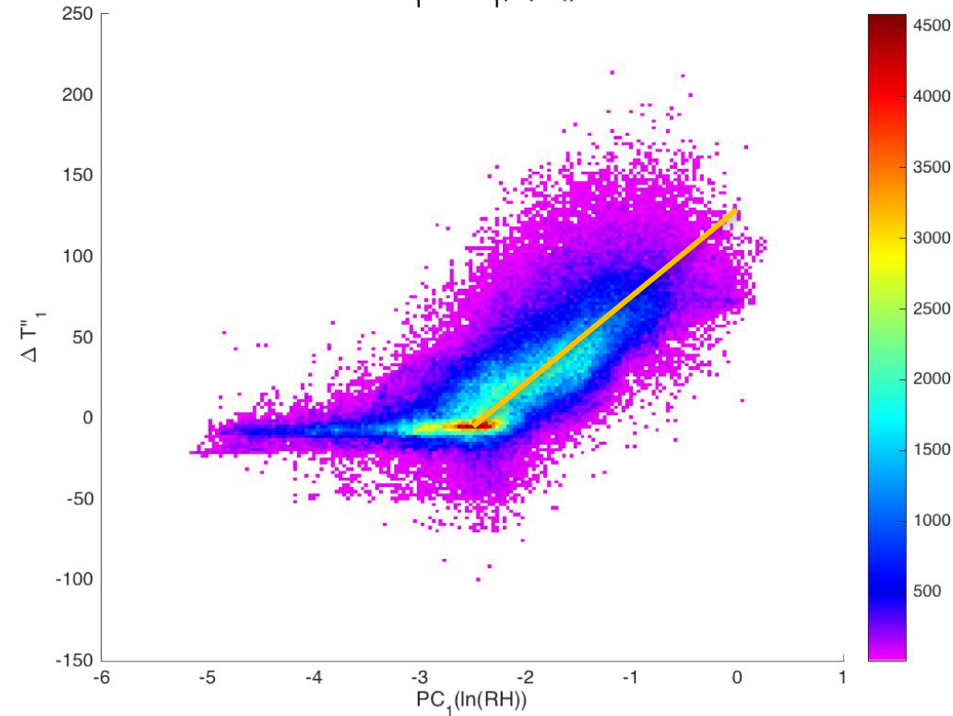




⇒ look for correlation between ΔT and vPCs of RH:

Step 2 – departure from mean

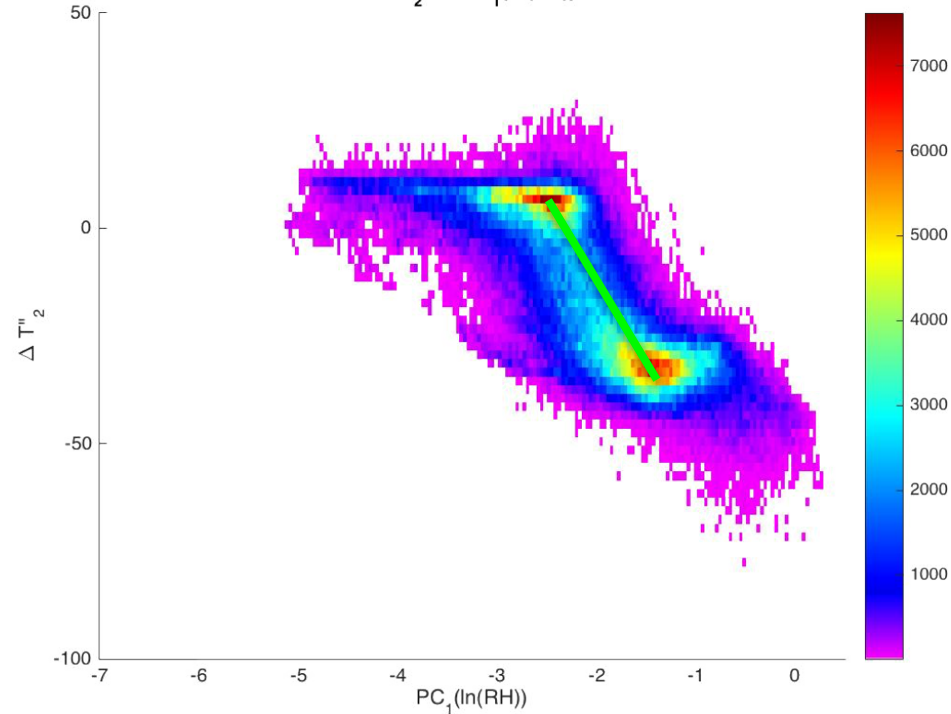
$\Delta T''_1$ vs. $PC_1(\ln(RH))$



$$\Delta T''_1 = (T''_1)_{MHS} - E(T''_1 | PC_1(CW), PC_2(CW))$$

$$\Delta T''_2 = (T''_2)_{MHS} - E(T''_2 | PC_1(CW), PC_2(CW))$$

$\Delta T''_2$ vs. $PC_1(\ln(RH))$



Simulation shows that $T - (\cdot | CW)$ is indeed correlated with RH !



⇒ **Semi-empirical approach (both steps combined):**

$$T_1'' = E(T_1'' | PC_1(CW), PC_2(CW)) + E(\Delta T_1'' | PC_1(RH))$$

$$T_2'' = E(T_2'' | PC_1(CW), PC_2(CW)) + E(\Delta T_2'' | PC_1(RH))$$

from database of coincidences

from model simulations with
empirically consistent mm-wave signatures

